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THE MEASUREMENT OF SUNSHINE AND THE PRELIMINARY EXAMINATION OF ANGSTRÖM'S PYRHELIOMETER.

C. F. MARVIN, Professor in charge Instrument Division.

While the writer was in attendance last August at the convention of Weather Bureau officials held in Milwaukee he was plied with numerous questions pertaining to the instrumental work of the Weather Bureau, many of which related to the measurement and registration of sunshine, especially in varying degrees of intensity. The sunshine recorders[1] at present in use at Weather Bureau stations are recognized as at best but imperfect, and the records only approximate and incomplete.

The urgent need of decidedly improved apparatus for this purpose is keenly appreciated by many of our officials whose close daily relation with agricultural interests emphasizes the incomplete character of the data at present available. The subject is one, however, which is but imperfectly understood by the majority of those who discussed the question with me, and it seems appropriate, therefore, at this opportunity to preface the present account of the comparison of pyrheliometers with a few brief statements of the general principles underlying measurements of solar radiation.

The present state of our knowledge of this intricate and deeply involved problem has just been summarized by Mr. Frank W. Very[2] in an excellent article which is recommended to everyone studying this question. This writer, however, as necessity compells in so condensed a summary, presupposes a reasonable acquaintance with the subject on the part of his readers, whereas, it is desired in what follows, to set forth briefly such elementary facts and principles as will help the

[1] Annual Report of the Chief of the Weather Bureau, 1891-92, p. 30; Annual Report of the Chief of the Weather Bureau, 1893, p. 18.
[2] The Solar Constant. MONTHLY WEATHER REVIEW, August, 1901, p. 357.

less fully informed reader to more perfectly comprehend the whole subject.

The solar energy which, when received at the surface of the earth, produces all our optical, thermal, electric, and chemical phenomena, obviously must first traverse the envelope of atmosphere surrounding the earth. This atmosphere even when in the clearest condition absorbs or intercepts at least a small part, and, under less favorable conditions, a very considerable part of the energy which arrives at its extreme outer limits. Measurements therefore of solar radiation made in the lower regions of the atmosphere necessitate also a study of the absorption by the atmosphere. The absorption of the radiant solar energy by gases and vapors and its dispersion and diffusion by dust and other minute constituents of the atmosphere are exceedingly complex phenomena, and are, in fact, at the best but partly understood or measured quantitively at the present time.

It is well known that ordinary white sunlight is made up of all the colors of the rainbow. It is, perhaps, less generally known that this so-called "visible spectrum" is but a small part of the whole solar spectrum, portions of which, invisible to the human eye, extend beyond the violet and especially far below the red. All these successive portions correspond, respectively, to radiant solar energy of different wave lengths. Some of the waves traverse the atmosphere with almost perfect facility, whereas others are in part, and some almost wholly, suppressed or absorbed and dispersed; and no study of atmospheric absorption can be complete without a full analysis of the "selective absorption" of the waves of different length by the air and its constituents. It is plain to be seen that this task is both complex and difficult to accomplish in a highly satisfactory manner.

For agricultural purposes, however, the heat effect actually produced at the surface of the earth is the desideratum, and we need very much an instrument that will measure and register this hour by hour and day by day, much the same, for example, as we now measure the movement of the wind hour after hour, or the amount of precipitation season after season.

Impressed with the visible heating power of the sun as shown by its effects on thermometers and articles generally exposed to its direct influence, almost every one seeking to measure this radiant energy is apt to set out with a thermometer, especially one with a blackened bulb, the indications of which are considered to measure in degrees the intensity of solar radiation. This is a serious mistake, but it is embraced so generally that it can not be too strongly condemned. I do not mean to imply that observations of temperature in the sunshine can not be used to measure solar radiation, but for this purpose secondary observations of other conditions are equally important, and, at the best, many difficulties are encountered. The whole matter will, I think, be much better understood by a concrete illustration.

Suppose I desire to measure the rainfall during a storm, but that I have for this purpose a rain gage such as indicated in Fig. 1. We will suppose this vessel is made of glass, so that the contents within may be seen from the outside, and that the slender stem is graduated. The point at which this gage differs essentially from an ordinary gage is that the bottom has a hole in it at *A*. Furthermore, I am obliged to use this gage with the bottom open. I expose it so that the rain falls into it freely, and I will assume that the hole in the bottom is not so large but that even with a slow rainfall at least a small quantity of water will stand in the tube at the bottom. Now, what shall we find with such a gage as this? If the rain falls continuously, it will be seen that the water rises in the graduated tube and stands steadily at a certain point, such that the water runs out of the hole in the bottom just as fast as it flows in at the top. If the rain falls more rapidly, the water will stand at a higher point in the tube, but it will also run out at the bottom more rapidly. Obviously, it will stand lower and run out more slowly when the rain falls less rapidly, etc. We might experiment with this gage by dropping or pouring water into it until the column attained a certain height, then, suddenly cutting off the inflow, we could note the exact time required for, say, a cubic inch of water to run out at the bottom. From a series of experiments like this, with suitable variations, we could develop at least two important laws of action of the gage, namely: first, that the rate of outflow differs noticeably for each height of the column; second, that for a given height of the column the rate of outflow is sensibly the same every time the experiment is repeated. Finally, the quantity of outflow, and hence of inflow, corresponding to each point of the graduated scale would be established. Such a gage can, it is true, be used for measuring rainfall, but everyone will admit it is far from a convenient or satisfactory instrument for this purpose. Bad as it is, however, it is better for measuring precipitation than is a thermometer placed in sunshine for measuring solar radiation.

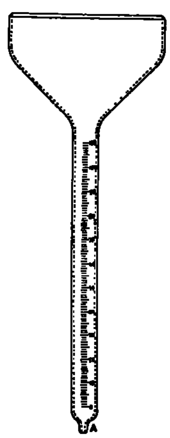


FIG. 1.

The trouble in both these instruments is that the water in the one case and the heat in the other escapes as fast as it is received. When the column of the thermometer is stationary it loses heat just as fast as it receives it, but, unlike the rain gage, which, as we have seen, loses and receives water always at the same rate for a given indication of the column, the heat lost and received by the thermometer has practically no definite relation to the height of the column of mercury; in fact, we are obliged to measure the loss in some way for each particular case. In the rain gage the water is received only at the top and lost only at the bottom; the thermometer, however, receives and loses heat in a great variety of ways. Heat is exchanged, for example, by radiation to and from every surrounding object; by convection currents in the air, or by the wind; by conduction along the stem, etc. It is plain to be seen that all these circumstances greatly complicate the use of thermometers in all such measurements as we now have under consideration.

The point we want to emphasize and present in a forcible manner in this illustration of the rain gage is that in the case of the thermometer there is an irregular outflow of heat, as well as an inflow, that must be looked after and carefully included in all considerations. Those who have but partly studied the subject often direct attention quite wholly to the inflow, or they virtually assume that the outflow is an invariable one, and hence are led to erroneous conclusions.

It is not the purpose of the present paper to describe the relatively complicated processes that have been developed by which to measure solar radiation, but it is plain that any apparatus which registers only variations in the temperature indicated by a thermometer exposed directly to sunshine fails to give any useful record of solar radiation, unless the irregular exchange of heat with the surroundings is fully controlled or compensated.

A little thoughtful consideration of the fact that we are actually dealing with an outflow, as well as an inflow of heat in this problem leads us at once to the next important consideration, namely, that units of temperature are not suitable units in which to measure solar radiation. We measure water in pounds, or gallons, or cubic feet. We measure heat in thermal units, or calories. With possible rare exceptions the metric units are now the only ones employed in measures of solar radiation, and in this case the unit is the calorie, that is, the quantity of heat required to raise one gram of water 1° in temperature on the centigrade scale. This quantity of heat is also often called the gram-calorie, in order to distinguish it from a much larger quantity of heat, also unfortunately called a calorie, namely, the quantity of heat required to raise the temperature of a kilogram of water 1° centigrade.

The foregoing considerations indicate the lines along which improvement in instruments for measuring and recording sunshine must be worked out. Many valuable suggestions will be found in a report by Violle in the Proceedings of the International Meteorological Committee, St. Petersburg meeting, 1898.

Solar constant.—Having outlined in what precedes the fundamental principles which must guide us in studies of solar radiation, we will state briefly the general numerical results of the most satisfactory measurements thereof and the value of the solar constant deduced thereby.

The intensity of the solar radiation, received and measured at the surface of the earth, varies greatly depending upon the condition of the atmosphere and the thickness of the layer of air traversed by the solar rays as modified by the latitude of the place, the hour of the day, the season, the altitude, or the barometric pressure, etc. Under the most favorable conditions when the sun is in the zenith it may attain to almost 3 gram-calories per square centimeter per minute. That is to say, if all the solar heat which falls on a square centimeter of surface, normally exposed to the sun is expended in warming water, the heat will increase the temperature of almost 3 grams of the water 1° centigrade in each minute of time. Ordinarily, however, owing to the interception by the atmosphere of considerable portions of the heat the value is much less than three calories.

Taking the maximum readings of solar radiation that may be obtained from time to time and applying such corrections to each as shall compensate for the loss of heat in transit through the atmosphere at the time, we obtain the so-called "solar constant," that is to say, the heat received from the sun at a point just outside our atmosphere. To be strictly accurate this value must be reduced to one corresponding to a definite distance from the sun, as the distance of the earth from the sun undergoes certain well known annual changes.

From the best data now available on this subject, it seems that the solar constant, as defined above, is about 3.1 gram-calories per square centimeter per minute.

The Weather Bureau has recently undertaken a series of special studies of the whole question as to the value of the solar constant and its variations, if any, with time, and the remainder of this paper will be devoted to a brief description of the preliminary tests and intercomparisons of the Angström electric compensation pyrheliometers to be employed in this work.

The apparatus is designed primarily with a view to easy portability and its use in the field, on mountain tops, and in places remote from the usual facilities of installation. The pyrheliometer with all its accessories, mounted on a slender tripod, is shown in Plate I. The total weight, packed in the carrying case is 19½ pounds.

The pyrheliometer proper is within the tube, *AB*. The galvanometer and telescope, by means of which temperature adjustments are effected, as will be more fully explained hereafter, are suspended at *C*. *D* is a small slide wire rheostat. *H* is an ammeter with which the strength of the electric current is measured. The carrying case with a single cell of Leclanche battery is seen below.

The mechanism of the pyrheliometer is shown in the upper left-hand corner of Plate I, and occupies about one-half the length of the tube, *AB*. *A* and *B* are two very thin bands of platinum foil, about 1.5 millimeters wide and 20 millimeters long. The back of each band is coated with a thin layer of silk insulating paper, and cemented against this is a thin strip of copper foil, very similar to the platinum bands themselves. Finally, the middle points of the copper strips are joined to each other by a small inverted ∩-shaped piece of constantan[3] wire. A portion of this wire is plainly seen at *c c*. The ends are hammered down thin near the junction with the copper bands. The several parts are so mounted that the copper bands are in electrical connection with the small lateral rods terminating at *T* and *T'*, respectively. The opposite ends of these rods terminate in binding screws, one of which can be partly seen at *E*. Both platinum bands are joined at the lower end to the terminal, *F*, and at the top end connect respectively to the terminals, *G* and G' *L* is the top end of a switch lever. In the position shown the electrical circuit is closed through *G* and the platinum strip, *A*. When the switch is thrown to the right the circuit is opened through *A*, and closed through *G'* and the band, *B*. The platinum bands are carefully coated with lampblack.

The pyrheliometer tube, *AB*, is closed at the upper end with a cap having two slits or openings. A small double shutter is pivoted back of this cap in such a manner that one or the other of the two openings can be closed by the shutter, or the shutter may be given a middle position in which both slits are open. A series of diaphragms with rectangular apertures, successively smaller, occupy the space in the tube between the cap and shutter and the platinum bands. These serve to intercept stray radiation and limit the exposure to the rectangular aperture across which the platinum bands, *A* and *B*, are stretched. A small thermometer, *t*, indicates, approximately, the temperature within the tube, *AB*.

The action of the instrument involves the use of two distinct and separate electrical currents. The one is the thermoelectric current produced by the constantan-copper thermoelectric junctions, *c*, *c*, on the back of the platinum strips. This current flows through the galvanometer and is generated only when there is a difference in temperature between the two bands, *A* and *B*. The other current is furnished by a cell of Leclanche battery, or equivalent. This current is controlled and its strength regulated by means of the rheostat, *D*, and then passes through one or the other of the bands, *A* or *B*, as determined by the position of the switch, *L*, thence through the ammeter, *H*, where the strength of the current is indicated.

The apparatus is set up so that the tube, *AB*, points directly toward the sun, as determined by means of suitable sights for that purpose. The shutter is first set so that both bands are exposed to the sun and are therefore equally heated. The needle of the galvanometer, *G*, is then adjusted, if necessary, so that the middle portion of the galvanometer scale, *S*, appears plainly in the field of view.

It is assumed the bands, *A* and *B*, are equally heated by the sun, as they must be, seeing that they are as similar as possible and are otherwise equally circumstanced. The thermoelectric junctions at *c*, *c*, on the back of the bands must, then, have the same temperature, and therefore no thermoelectric current flows through the galvanometer. The scale reading, under these conditions, is the zero position of the galvanometer. If now the shutter be turned so as to screen the band, *B*, for example, leaving *A* exposed to the sun, the shaded band will cool off and the galvanometer will deflect. Now, let a current from the battery be sent through the shaded band, *B*; the latter will be heated thereby, and by a suitable adjustment of the rheostat the galvanometer needle will be returned to its original zero position. This means that the shaded band, *B*, is now heated by the electric current sent into it until its temperature is the same as that of the band, *A*, exposed to the sun. We thus have two bands, themselves equal,

[3] This is an alloy which forms a strong thermoelectric couple with copper.

both at the same temperature, both in the same environment, both losing and receiving heat at the same rate; the one heated by the solar radiation, the other by an electric current. The amount of heat generated by the electric current is easily calculated with accuracy when we know its strength and the resistance of the platinum bands. Thus we are able to measure the solar radiation in a very satisfactory manner.

The following general instructions have been issued for the guidance of those using the pyrheliometers.

The apparatus being completely mounted the full details of a complete observation are about as follows:

1. Start with current off; i. e., rheostat switch on neutral point. Point tube to sun by aid of sights and set shutter in central position so that the sun heats both strips.
2. Note and record: *a*, the temperature of attached thermometer; *b*, the time; *c*, the zero position of galvanometer.
3. Designating the two strips by the letters *A* and *B*; screen *B* and set switch at back of tube so that current passes through *B*.
4. Cut in current and adjust rheostat, so that the galvanometer needle returns as nearly as may be to the zero reading recorded under (2).
5. When the adjustment under (4) is attained read and record ammeter.
6. Screen *A* and switch current through it and readjust rheostat, if necessary, as in (4).
7. Read and record ammeter for No. 6 adjustment.
8. Note sights on tube and readjust pointing of pyrheliometer, if necessary.
9. With *A* still screened, readjust rheostat, if necessary, and restore galvanometer to zero.
10. Read and record ammeter.
11. Screen *B*; switch current through it and restore galvanometer to zero.
12. Read and record ammeter.
13. Set shutter in middle; i. e., expose both strips to the sun and cut off current at rheostat.
14. Read and record zero position of galvanometer.
15. Note and record time; also temperature of attached thermometer.

The following example is given of a set of readings forward and back on pyrheliometer No. 34.

October 29, 1901.	Temperature. Centigrade.	Bands exposed.			Gram-calories per sq. cm. per minute. Q.
		Both A and B.	A.	B.	
		Gal. reading.	*Amperes.*	*Ampere.*	
2:00 p. m.	21.9	153	.331	.325	0.778
2:05 p. m.	22.0	134	.335	.325	0.787

In computing the results the mean of the two determinations of current strength should be multiplied by the coefficient taken from Angström's table of constants corresponding to the temperature shown by the reading of the attached thermometer. (See Table 5.) The result is the gram-calories of heat received from the sun per square centimeter, per minute, as observed at that place and moment of time. From this the solar constant is to be determined by further investigations into the absorption by the atmosphere.

The observations may possibly be abridged somewhat without loss of accuracy, and, on the other hand, if difficulty is found in restoring the galvanometer to zero in a satisfactory manner, it may be necessary to record the reading and establish a slight correction for the discrepancy.

Before undertaking a direct comparison of the pyrheliometers it was necessary to compare the three Weston direct reading ammeters used in the measurement of current strength.

For this purpose the three instruments were joined in series with a battery and with an adjustable resistance, which latter was regulated so as to bring the index on ammeter No. 4321 to a particular division, whereupon an assistant noted, simultaneously, the readings on the two remaining instruments.

Each instrument has a double scale, one, the upper scale, from 0 to 500, divided into 100 equal parts; the other, the lower scale, from 0 to 10, also divided into 100 parts. The following table gives the readings made:

TABLE 1.—*Comparison of Weston ammeters.*

Scale readings (for upper scale).

No. 4321.	No. 4306.	No. 4315.
Amperes.	*Amperes.*	*Amperes.*
.0500	.0495	.0500
.1000	.0990	.0998
.1500	.1480	.1500
.2000	.1980	.2000
.2500	.2490	.2500
.3000	.2998	.3000
.3500	.3498	.3495
.4000	.3998	.4000
.4500	.4498	.4490
.5000	.5000	.4978

Scale readings (for lower scale).

No. 4321.	No. 4306.	No. 4315.
Amperes.	*Amperes.*	*Amperes.*
.00200	.00200	.00200
.00400	.00399	.00400
.00600	.00601	.006005
.00800	.008005	.00800
.01000	.01000*	.009995

* And off the scale.

The greatest discordance at any point seems to be about 1.3 per cent at 0.150 ampere on No. 4306.

Next the pyrheliometers, in pairs, were directly compared in the sunshine. In the first comparison, October 25, the readings were not made forward and back, in the manner explained in the instructions, but were recorded directly in the order indicated.

The results are given in full in the accompanying tables.

The column of results headed "calories, etc.," is computed by the equation—

$$Q = k\left(\frac{A+B}{2}\right)^2$$

in which the value of the constant k is taken from Table 5 for the particular instrument in question, and the corresponding temperature recorded for the observation.

TABLE 2.—*Comparison of Angström's pyrheliometers.*

Oct. 25, 1901. Time, p. m.	Pyrheliometer No. 31. Ammeter No. 4321.					Pyrheliometer No. 34. Ammeter No. 4306.				
	Band exposed to sun.			Temperature, C.	Q.	Band exposed to sun.			Temperature, C.	Q.
	Both A and B.	A.	B.		Cal. per sq. cm. per min.	Both A and B.	A.	B.		Cal. per sq. cm. per min.
	Gal. zero.	*Amp.*	*Amp*	°		*Gal zero.*	*Amp*	*Amp*	°	
2:05	117	.398	.396	18.0	1.12	110	.380	.385	16.1	1.05
2:17	115	.402	.400	18.0	1.14	118	.378	.403	16.0	1.10
2:22	115	.403	.405	18.5	1.16	84	.402	.405	16.0	1.18
2:24	117	.398	.396	17.5	1.13	102	.395	.396	16.0	1.18
2:34	118	.395	.403	18.6	1.13	95	.400	.385	16.5	1.11
2:38	120	.391	.400	18.1	1.12	105	.388	.388	16.5	1.09
2:42	117	.398	.398	18.1	1.13	102	.395	.387	16.0	1.10
2:49	121	.394	.385	17.2	1.08	95	.398	.395	16.0	1.13
2:52	115	.388	.397	17.3	1.09	90	.407	.372	16.5	1.10
2:58	119	.384	.382	17.2	1.04	120	.370	.397	16.1	1.06
3:02	116	.380	.386	17.0	1.04	98	.380	.382	16.0	1.05
Mean of 11 observations					1.106	....				1.100

TABLE 3.—*Comparison of Angström's pyrheliometers.*

Oct. 29, 1901. Time, p. m.	Pyrheliometer No. 28. Ammeter No. 4315. Temperature, C.	Band exposed to sun. Both A and B.	A.	B.	Q. Cal. per sq. cm. per min.	Pyrheliometer No. 34. Ammeter No. 4306. Temperature, C.	Band exposed to sun. Both A and B	A.	B.	Q. Cal. per sq. cm. per min.
	°	*Gal. zero.*	*Amp.*	*Amp.*		°	*Gal. zero.*	*Amp.*	*Amp.*	
1:30	21.6	125	.308	.340	.815	21.2	117	.339	.350	.854
1:37	21.6	184	.295	.338	.795	21.0	106	.341	.350	.864
1:40	21.5	126	.299	.345	.820	21.0	111	.330	.350	.835
1:45	21.4	188	.308	.335	.805	21.0	88	.345	.352	.874
1:47	21.8	126	.300	.340	.810	21.5	95	.347	.341	.855
1:52	21.9	141	.303	.335	.804	21.9	89	.344	.343	.855
1:54	21.5	128	.298	.335	.795	21.9	144	.352	.342	.870
1:57	21.7	145	.295	.330	.770	21.9	148	.341	.341	.841
2:00	21.1	185	.285	.325	.785	21.9	158	.331	.325	.778
2:05	21.0	150	.293	.315	.780	22.0	134	.335	.325	.787
2:09	21.0	184	.297	.310	.725	21.0	186	.315	.364	.835
2:13	21.1	149	.292	.310	.716	21.7	165	.307	.364	.816
2:18	21.0	129	.290	.310	.711	21.6	165	.327	.362	.855
2:25	21.5	150	.252	.306	.698	21.2	130	.300	.357	.777
2:26	21.5	189	.288	.317	.712	21.3	188	.330	.320	.762
2:31	21.2	150	.285	.312	.702	21.0	110	.353	.318	.815
2:34	21.4	142	.282	.312	.698	21.0	116	.348	.298	.758
2:39	21.2	148	.280	.305	.674	21.0	157	.293	.290	.616
2:40	21.2	142	.283	.308	.678	21.1	160	.308	.335	.749
2:44	21.1	155	.275	.301	.655	21.0	113	.330	.333	.796
Mean of 10 pairs of observations					.7424					.8096

The constants of the instruments were very carefully determined by Knut Angström, and are combined in the following table:

TABLE 4.—*Constants of pyrheliometers.*

	No. 28.	No. 31.	No. 34.
Electrical resistance of the bands at 20° C. (r)	0.0810	0.0731	0.0751
Coefficient of variation of resistance with temperature	.00045	.00045	.00045
Width of bands (b) centimeters	0.150	0.150	0.152
Absorbing power of the surfaces (a)	0.98	0.98	0.98

The intensity of radiation is given by the relation

$$Q = \frac{r\, i^2}{4.19\, b\, a}\, 60 \text{ gram-calories per min. per cm.}^2$$

Or $$Q = k\, i^2.$$

(i = intensity of the current in amperes.)

The coefficient k has, at different temperatures, the following values:

TABLE 5.

Temperature, C.	−10°	0°	10°	20°	30°	40°
Instrument.	k.					
No. 28	7.80	7.83	7.87	7.90	7.94	7.97
No. 31	7.02	7.06	7.09	7.13	7.16	7.19
No. 34	7.12	7.15	7.19	7.22	7.26	7.29

NOTES BY THE EDITOR.

WEATHER BUREAU MEN AS INSTRUCTORS.

Mr. George E. Franklin, Local Forecast Official, Los Angeles, Cal., has given instruction to the class in physical geography of the Los Angeles High School in the construction and use of meteorological instruments and the general work carried on at stations of the Weather Bureau. For this purpose the class, which numbers about 150, visited the local Weather Bureau office in sections on different days during the latter part of the month. Similar instruction is to be given to the pupils of other schools during the winter.

Mr. A. E. Hackett, Section Director, Columbia, Mo., has undertaken the instruction of a class in climatology in the Missouri State University. The class meets each Friday during the first semester and a greater portion of the time will be devoted to the study of the more important climatic features of the various sections of the United States. This course is now required in the Missouri State University for the degree of Bachelor of Science in Agriculture.

Mr. H. W. Richardson, Local Forecast Official, Duluth, Minn., reports that on October 24 he addressed the senior class of the Convent of the Sacred Heart at his office, the topic being the United States Weather Bureau. On October 29, the senior class of young ladies from the Craggencroft Private School, Duluth, Minn., visited the office and after explaining the various instruments, Mr. Richardson addressed them upon Weather Forecasting and the Work of the United States Weather Bureau.—*H. H. K.*

APPLIED CLIMATOLOGY.

By practical climatology we ordinarily mean the observing and recording of the weather, the preparation of mean values and the application of this climatological knowledge to the benefit of mankind. Practical meteorology implies similar observations but a different form of record, i. e., the daily weather map and the study and prediction of storms and changes in the weather.

There are many other fields for the application of our knowledge of climatology and one of the most interesting is that branch of geography called physiography or the study of the action of the atmosphere in altering the surface features of the earth.

As many of the readers of the MONTHLY WEATHER REVIEW are teaching geography, climatology, and physiography, we believe that they will often find opportunity to utilize ideas drawn from the following outline of the subjects treated of by Prof. Dr. George B. Shattuck of Johns Hopkins University in his recent course of public lectures in Baltimore.

GEOGRAPHY OF NORTH AMERICA.

LECTURE I.

SUBJECT.—PHYSIOGRAPHIC FEATURES OF NORTH AMERICA.

Relations of continental plateaus and ocean basins.—Methods of sounding: lead line; Sigsbee sounding machine. Contour of ocean bottom: levels; ridges; deeps. Contour of continental plateaus: continental shelf; submarine earthquakes; cable ruptures.

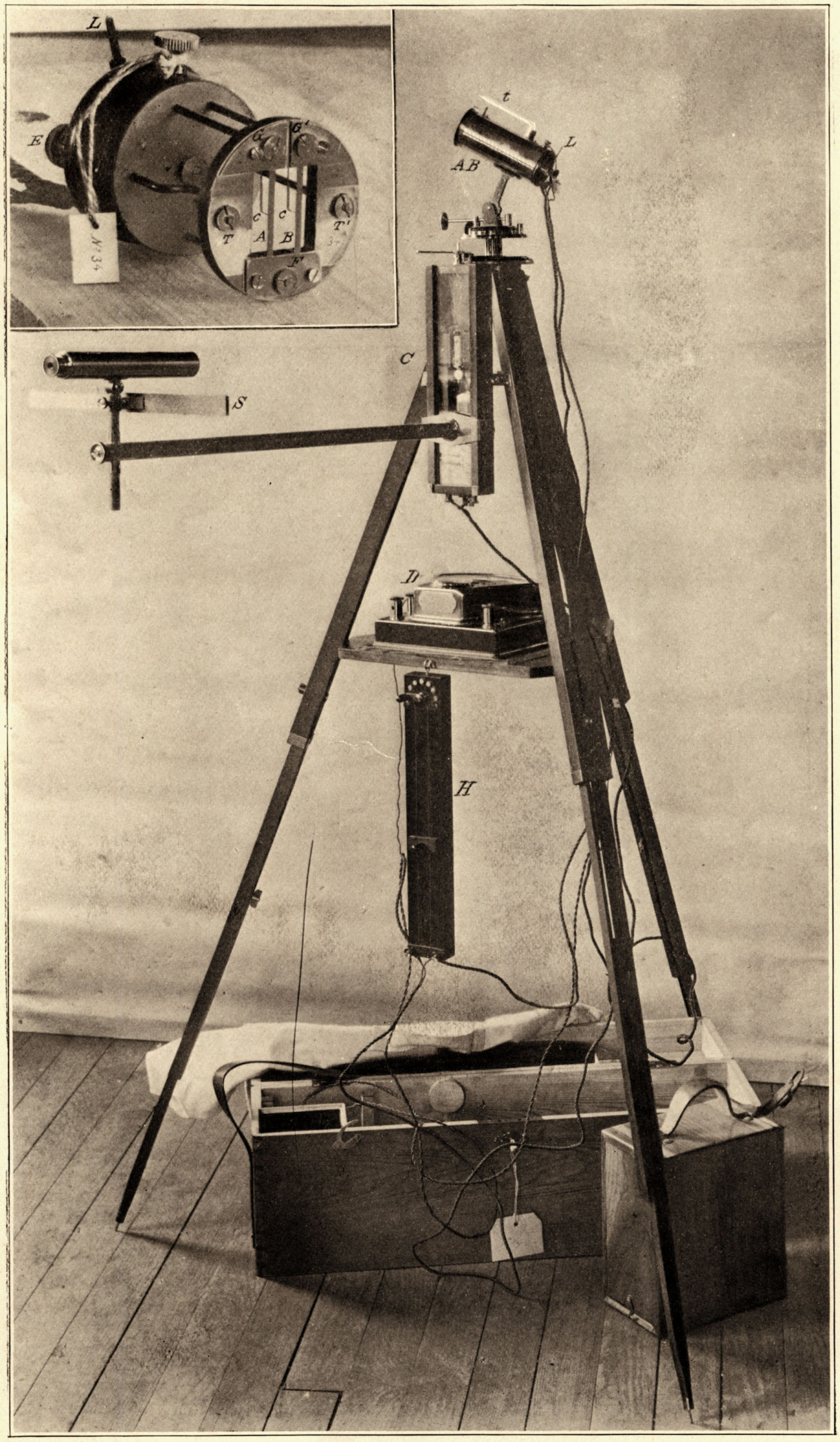
Relations of North America to the other continents and to the surrounding ocean basins.—Atlantic basin; Pacific basin; Arctic basin; Antillian basin.

Hypsometric features of North America.—Atlantic Plain: position; extent; characteristics; subdivisions—Coastal Plain, Piedmont Plateau. Appalachian Mountain System: position; extent; characteristics; subdivisions—Blue Ridge, Appalachian Valley, Cumberland-Allegheny Plateau. Great Central Plain: position; extent; characteristics; subdivisions—Laurentian Highlands, Mackenzie River Basin, St. Lawrence Valley, Mississippi Valley, Prairie Steppes, Black Hills, Ozark Mountains, Llano Estacado, Bad Lands. Cordilleran Mountain System: position; extent; characteristics; subdivisions—Rocky Mountains, Plateau Country, Great Basin, Coast Ranges. Antillian Mountain System: position; extent; characteristics; subdivisions—Greater Antilles, Lesser Antilles, Bahamas, Trinidad-Tobago group, Mountains of Central America.

LECTURE II.

SUBJECT.—CLIMATOLOGY AND HYDROGRAPHY.

Climatology.—Definition of climate: precipitation: evaporation; circulation; condensation; storms; distribution of rainfall. Temperature: heat in atmosphere; ocean currents—horizontal, vertical; mean annual temperature; variation in temperature.



Angström's Portable Electrical Compensation Pyrheliometer.